Failure patterns of different bracket systems and their influence on treatment duration: A retrospective cohort study

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Abstract: OBJECTIVES To compare the failure pattern of four different bracket types and to assess its effect on treatment duration. MATERIALS AND METHODS A total of 78 white patients (28 male, 50 female) with a mean age of 12.6 years were included in this retrospective cohort study and treated for a mean period of 30.6 months. The patients were treated in a private practice with stainless steel conventionally ligated brackets, ceramic conventionally ligated brackets, stainless steel self-ligating brackets, or nickel-free self-ligating brackets. The loss of at least one bracket during the course of treatment was analyzed with Cox proportional hazards survival analyses and generalized linear regression. RESULTS The overall bracket failure rate at the tooth level was 14.1% (217 brackets), with significant differences according to tooth type (between 8.0%-23.4%) and bracket type (between 11.2%-20.0%). After taking confounders into account, patients treated with ceramic brackets lost more brackets (hazard ratio = 1.62; 95% confidence interval = 1.14-2.29; P = .007) than patients with stainless steel brackets. On average, treatment time increased by 0.6 months (95% confidence interval = 0.21-1.05; P = .004) for each additional failed bracket. CONCLUSIONS Bracket failure was more often observed with ceramic brackets and was associated with increased treatment duration.

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Failure patterns of different bracket systems and their influence on treatment duration: A retrospective cohort study

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NO COLOR FIGURES

ABSTRACT

Objectives: Bracket failure occurs in patients receiving fixed-appliance treatment and affects directly the duration of the treatment. Aim of this retrospective cohort study was to compare the failure pattern of four different bracket types and to assess its effect on treatment duration.

Materials and Methods: A total of 78 Caucasian patients (28 males, 50 females) with a mean age of 12.6 years were included in the present study and treated for a mean period of 30.6 months. Patients were treated in a private practice with stainless steel (SS) conventionally-ligated brackets, ceramic conventionally-ligated brackets, SS self-ligating (SL) brackets or nickel-free SL brackets. Loss of at least one bracket in the course of treatment was analyzed with Cox proportional hazards survival analyses and generalized linear regression.

Results: The overall bracket failure rate at tooth level was 14.1% (217 brackets), with significant differences according to tooth type (between 8.0%-23.4%) and bracket type (between 11.2%-20.0%). After taking confounders into account, patients treated with ceramic brackets lost more brackets (Hazard Ratio=1.62; 95% Confidence Interval (CI)=1.14,2.29; P=0.007) than patients with SS brackets. On average, treatment time increased by 0.6 months (95% CI=0.21,1.05; P=0.004) for each failed bracket.

Conclusions: Bracket failure was more often observed with ceramic brackets and is associated with increased treatment duration.

KEY WORDS: bracket failure; treatment duration; treatment efficiency; survival analysis; clinical study

INTRODUCTION

Clinical efficiency and treatment duration in orthodontics can be compromised by bond failure.[1-3] Indeed, bracket failure is ranked as one of the most important predictors of fixed appliance treatment duration, along with patient compliance, treatment variations, such as office-related treatment approaches, multiple phases and extractions, as well as appliance selection and underlying malocclusions,[1,2,3] with an extension of treatment by 0.3 months for every bracket failure and up to 1.5 months for 3 or more failures, as the clinician may have to temporary delay the originally planned succession of wires and multiple failures might reflect a lacking level of patient compliance.[2,3] Keeping the fixed appliance phase as short as possible is to the best interest of both patient and orthodontist, therefore it is prudent to effectively control all factors that could prolong treatment duration.[4,5]

Considerable focus has been placed in the last decades on enhancing the efficiency of orthodontic treatment through stimulation of patient compliance, modification of orthodontic appliances or bonding techniques and use of various adjuncts.[6-8] However, existing evidence behind many of these measures is still lacking and there is often insufficient support for their use to improve treatment efficiency.[9,10] Studies have shown that bonding performance of orthodontic appliances differs depending on factors such as tooth type and position, type of bonding agents and curing methods, as well as bracket mesh types and materials and aging and attrition of the bond in oral conditions. Among the various study designs to evaluate the effect and interaction of these factors, in vivo clinical studies are probably best suited for the formulation of clinical recommendations of efficacy, as the complex influencing factors cannot be simulated satisfactory in in-vitro and ex-vivo studies leading consequently to conflicting results, therefore being of little clinical significance.[11,12]

Therefore, aim of the present retrospective clinical cohort study was to assess in a clinically-relevant way the failure pattern of different bracket systems and their effect on orthodontic treatment with fixed appliances. The effect of bracket failure on treatment duration was also assessed, as a secondary outcome.

MATERIALS AND METHODS

Due to the retrospective character of this study the Ethical Committee of the University of Bonn raised no ethical concerns. This study was based on a convenience sample from clinical archives of patients consecutively-treated by the same doctors with fixed appliances in a span of 5 years (2011-2016) in a private orthodontic practice in Bergheim, Germany. Patient eligibility was based on: (i) clear

medical history, (ii) complete permanent dentition (with the possible exception of third molars), (iii) no cases transferals from other practices, (iv) complete documentation, (v) achievement of treatment goals (no early termination/drop-outs), and (vi) loss of at least one bracket. The latter was set, as it was aimed to assess the relative failure pattern of various brackets and not absolute survival.

A total of 78 patients (28 male/50 female) could be recruited, who received treatment with fixed appliances with bonded attachments on all teeth, except molars that were banded and are not assessed here. The following 4 bracket systems (0.022”-slot) were used: (1) conventionally-ligated Stainless Steel (SS) brackets (Mini Master, MBT prescription, American Orthodontics, USA) in 25 patients; (2) conventionally-ligated ceramic brackets (Clear Comfort, MBT prescription, West Ortho, Germany) in 20 patients; (3) self-ligating SS brackets (Damon 3MX, Ormco, USA) in 25 patients; and (4) self-ligating Ni-free SS brackets (Bio Quick LP, MBT prescription, Forestadent, Germany) in 8 patients. Patients included in this study were presented during treatment planning with information regarding all available bracket systems in the practice, in form of brochures and personalized consultation based on the patient’s input (like Nickel allergy or aesthetic concerns) and bracket system to be used was chosen by the patient.

The same bonding protocol was used in all cases, according to manufacturer’s instructions. Enamel surfaces were pumiced and then etched with 37% orthophosphoric acid for 30 seconds, thoroughly rinsed with water for 10 seconds, and dried. The same bonding adhesive and resin were employed (Light Bond™ Filled Sealant & Light Bond™ Composite, Reliance Orthodontics Products, Itasca, Illinois, USA). Brackets were placed by 3 doctors (including the practice owner), while bracket placement and all treatment phases were supervised by the practice owner. All conventionally-ligated brackets were ligated using elastomeric ties.

Outcomes

The primary study outcome was the number of failed brackets at patient level, based on the patient’s files. Secondarily, time-to-failure was extracted at tooth level to assess the pattern of bracket failure and only first-time failure for each bracket was assessed, because multiple failures of the same bracket might be due to parafunction, detrimental habits, or flawed bonding protocol.[8 9] Finally, the duration of active treatment in months was extracted at patient level from insertion to removal of appliances.

Statistical analysis

Means and Standard Deviations (SD) [medians and Interquartile Ranges (IQR) for non-normally distributed data] were calculated for continuous outcomes and frequencies for binary outcomes after normality checks. Generalized linear negative binomial regression was used to identify factors associated with number of failed brackets per patient. Time-to-bracket failure was explored with survival analysis, and bracket failure Hazard Ratios (HR) adjusted for confounders were calculated with Cox proportional hazards regression with shared frailty, accounting for clustering of brackets within patients. Proportional hazard assumptions were assessed using log-log plots, comparing fitted and predicted Kaplan-Meier plots, and on basis of Schoenfeld residuals. Finally, treatment duration and the effect of bracket failure (among others) on treatment duration was assessed with linear regression.

For all regression analyses, an initial univariable model with each factor was run and only variables with P≤0.2 in the univariable model were included in a multivariable model adjusting for confounders like patient age, sex, and tooth-/ treatment-/ or malocclusion-related characteristics. Malocclusion-related characteristics, including the presence of deepbite, crossbite, or anterior crowding were extracted qualitative by visual inspection of the pre-treatment documents. All analyses were conducted with the STATA SE 14.0 (StataCorp, College Station, Tex) with a=0.05 and calculating 95% confidence intervals (CI).

RESULTS

The demographics of the sample are shown in Table 1. Mean treatment duration was 30.6 months and overall first-time failure for the sample was at 14.1% (217 from 1328 attachments; Appendix 1). Considerable differences existed according to tooth type with an 8.0% failure of canines, followed by 11.3% for 1st premolars, 13.1% for central incisors, 14.4% for lateral incisors, and 23.4% for 2nd premolars. Additionally, significant differences existed according to bracket type with 11.2% failure for SS self-ligated brackets, followed by 12.3% for SS conventionally-ligated brackets, 13.8% for Ni-free self-ligated brackets, and 20.0% for ceramic conventionally-ligated brackets.

As far as the primary outcome is concerned, a median of 3 failed brackets per patient was observed (Table 2), treatment duration and bracket type significantly associated with the number of bracket failures (Table 3). After adjusting for confounders, only treatment duration was associated with increased failure, with 0.1 failure for each additional month of treatment (95% CI=0.01-0.19 brackets), which is translated to an additional bracket failure every 10 months.

To take into account differences in treatment duration among patients, bracket failure was analyzed as a time-to-event variable (Table 4; Appendix 1). Compared to canine brackets (which showed the lowest failure rate), brackets at central incisors (HR=1.7; 95% CI=1.1-2.9), lateral incisors (HR=1.9; 95% CI=1.2-3.1), and second premolars (HR=3.2l; 95% CI=2.0-5.0) were at any particular time more prone to failure (Figure 1). Additionally, ceramic conventionally-ligated brackets were at any time 60% more prone to failure compared to SS conventionally-ligated brackets (HR=1.6; 95% CI=1.1-2.3; Figure 2).

Finally, factors influencing treatment duration were analyzed (Table 5; Appendix 2). Prolonged treatment duration was associated with the use of nickel-free self-ligating brackets compared to SS conventionally-ligated brackets (by 6.5 months; 95% CI=0.6-12.4 months) and with extraction treatment compared to non-extraction treatment (by 7.3 months; 95% CI=1.8-12.9 months). Furthermore, treatment duration was significantly prolonged by 0.8 months for each additional missed patient appointment (95% CI=0.2-1.5 month) and by 0.6 months for each additional failed bracket (95% CI=0.2-1.1 month).

DISCUSSION

This retrospective cohort study assessed the pattern of bracket failure during fixed-appliance treatment and treatment duration. This study indicates that the majority of patients lost more than one bracket during treatment (median of 3 failures; Table 2), while only 18/78 patients (23%) lost just one bracket, which agrees with previous studies.[3,7] The overall bracket failure rate at tooth level was 14.1%, which is higher compared to previously reported failure rates of 6-8%.[11,13,14] However, this might be due to the inclusion of patients with ≥1 failed bracket, in order to explore the relative bracket failure pattern among patients.

Additionally, the mean treatment duration of 30.6 months found in the present study might be longer than the average duration found in the literature.[5] This might be explained by a wide malocclusions spectrum that is usually excluded from controlled trials, or by the use of bracket failure as an eligibility criterion.

As far as the pattern of failed brackets is concerned, significant differences were found according to tooth type, with canines being least prone to failure, followed by central incisors (+74% higher failure rate), lateral incisors (+89% higher failure rate), and second premolars (+219% higher failure rate) (Table 4), which is in agreement with the patterns observed in other studies.[8,14-16] Tooth-specific differences in

the bracket failure rate have been attributed to the increased risk of moisture contamination at certain sites, increased masticatory loads, and larger amounts of aprismatic enamel.[13,17,18] The higher incisor bracket failure compared to canines could be possibly explained by either increased activation forces due to anterior crowding or by increased mastication forces received during biting at food.

As far as the appliance's influence is concerned, significant differences were found between SS and ceramic brackets, with the latter being at any time during treatment significantly more prone to failure (Table 4). The structural integrity of ceramic brackets is lower than the more deformable SS brackets, [19] thus leading to material failure more easily.

Furthermore, a proportional relationship was found between additional bracket failure rate and treatment duration, with 0.11 more failed brackets for each additional month of treatment (or inversely, one additional bracket failure for every 9.1 months of treatment). This can be explained, considering that longer exposure of a bracket to the oral environment corresponds to longer exposure to various degrading factors to the bond surface, such as continuous, multi-vector occlusal forces, by-products of complex bacterial activity, possibly extreme pH conditions and variations in temperature.[12,20]

Additionally, bracket failure was found to significantly affect treatment duration, with an extra 0.6 month for each additional bracket failure (Table 5). Taking into account the median number of 3 failed brackets per patient (IQR=2-5 brackets), excessive bracket failure alone might lead to prolonged treatment by 1.8 months (IQR 1.2-3.0 months), which given the great efforts being made to accelerate orthodontic treatment in any way,[4,9] might be of importance.

Increased treatment duration was furthermore seen in extraction treatment and on the basis of missed patient appointments; both of these factors are straightforward and can be easily explained. Although temporal trends can be seen in the incidence of orthodontic tooth extractions the choice to extract teeth or not should be founded on systematic appraisal of the diagnostic records, treatment plan, and sound biological principles, which are evaluated in a case-by-case level.[21,22] Missed appointments on the other hand are a close proxy to patient compliance, with documented impact on bracket failure and treatment duration.[1,3] Interestingly, interventions aimed at improving patient compliance during orthodontic treatment have been found to reduce observed bracket failure and could lead to improved treatment efficiency.[6,23]

Finally, prolonged treatment duration was associated with the use of nickel-free SL brackets compared to SS conventionally-ligated brackets (Table 5), which could not be explained by an increased bracket failure rate for the former and is in line with previous evidence from randomized trials.[10] It might

be that the used SL brackets were less effective during the various treatment phases, like finishing or torque application, which have been reported to be problematic with certain SL brackets.[24,25] Another possible explanation is the possible wear-out of the SL bracket's clips, which in turn might have reduced the bracket's efficiency.[26] However, caution is warranted with the interpretation of this result, due to the non-randomized nature of the present study. Although inclusion of non-randomized studies is accepted to assess the adverse effects of interventions (like bracket failure), but this is more critical to judge the therapeutic effects of interventions (like treatment duration), where randomized clinical trials are the gold standard.[27]

The strength of the present study includes the use of objective and transparent eligibility criteria to select patients from a pool of consecutively-treated patients and the detailed extraction of patient-, appliance-, and treatment-related characteristics, which were appropriately analyzed to assess bracket failure and its effect on treatment duration.

However, several limitations are also present. First and foremost, this was a non-randomized historical (retrospective) cohort study—a design that has been shown to be more prone to bias than prospective clinical studies, and especially randomized ones.[27-29] Therefore, explorative inferences can be drawn from the present study as far as demographic patient- or tooth-specific characteristics related to bracket failure are concerned, but no sound evidence can be attained regarding the comparative effectiveness of the various brackets in treating malocclusions. Additionally, included patients were treated by three different clinicians, which might have influenced the study's results. However, all clinicians had been trained and were working in the same practice using the same bonding and treatment approach for the past 5 years, while all treatment phases were directly supervised by the practice owner (F.K.). Finally, no sample size calculation was performed, as this study was based on the application of a priori set eligibility criteria upon a convenience sample of all available patients treated in the last 5 years by the same doctors. Therefore, results – especially for the subgroup of Ni-free brackets or extraction cases – should be viewed as having potentially low statistical power.

The results of the present study could be generalized to the average Caucasian patient being treated mostly non-extraction with a wide array of directly bonded buccal fixed appliances in an orthodontic specialty practice by experienced clinicians. They might be less applicable to patients treated in university clinics or patients treated with indirect bonded, lingual, or custom-made appliances.

CONCLUSIONS

Based on the results of the present retrospective cohort study with its inherent limitations, the following conclusions can be drawn:

- Multiple bracket failures are clustered in certain patients with a median of 3 failed brackets per patient.
- Tooth-specific differences in bracket failure rate were seen, with canines having the lowest failure rate, followed by incisors, and premolars.
- Ceramic conventionally-ligated brackets were at any time more prone to failure than stainless steel brackets—be it conventionally-ligated or self-ligated.
- Bracket failure was directly associated with prolonged treatment time by 0.6 months for every additional failed bracket.

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FIGURE LEGENDS

Figure 1: Kaplan-Meier plot for bracket survival according to tooth category. Compared to canine brackets (lowest bracket failure rate observed), brackets at central incisors (HR=1.7; 95%=1.1-2.9), lateral incisors (HR=1.9; 95% CI=1.2-3.1), and second premolars (HR=3.2l; 95% CI=2.0-5.0) were at any particular time significantly more prone to failure.

*1s, upper/lower central incisors; 2s, upper/lower lateral incisors; 3s, upper/lower canines; 4s, upper/lower first premolars; 5s, upper/lower second premolars.

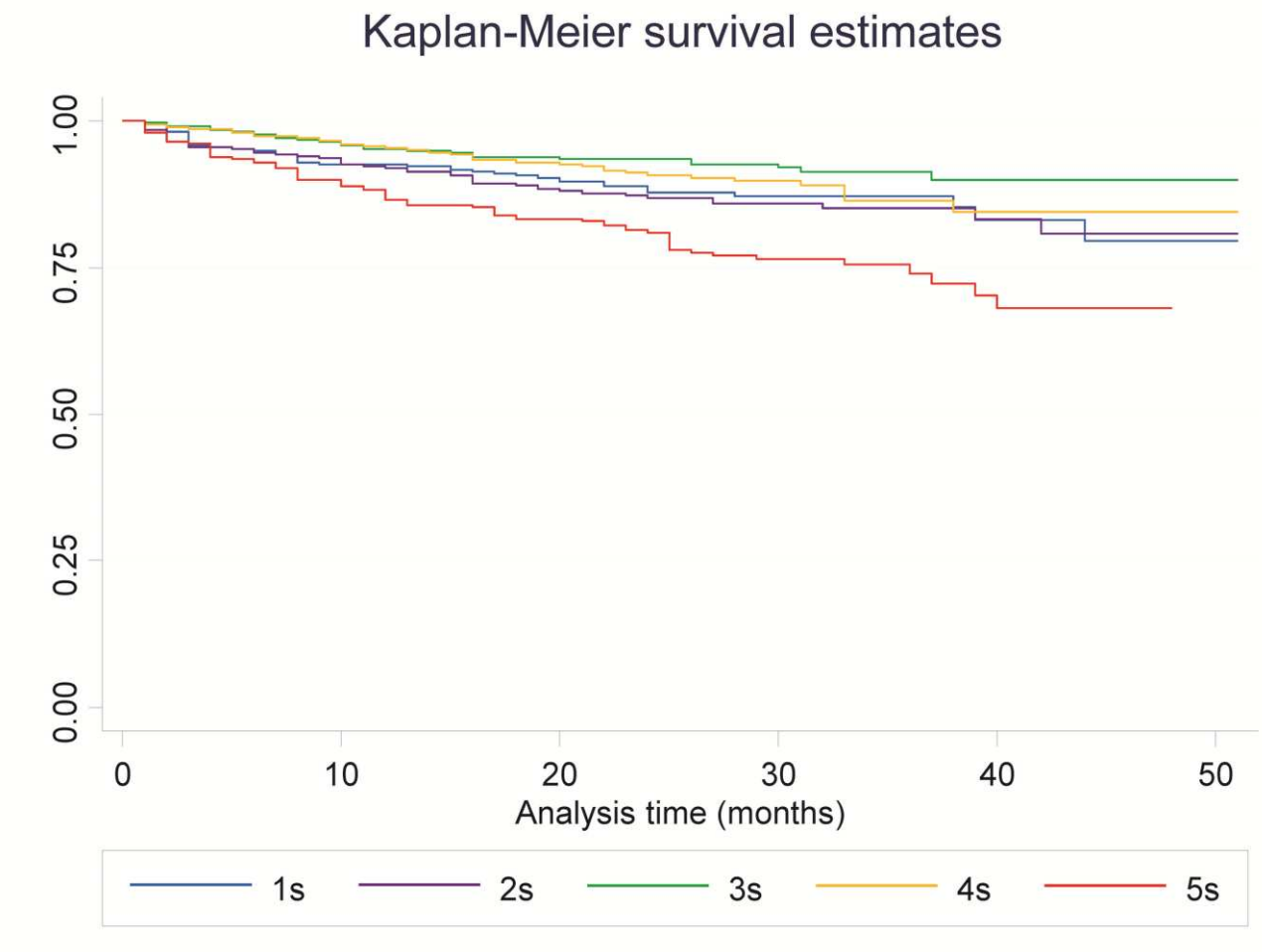

Figure 2: Kaplan-Meier plot for bracket survival according to bracket system. Ceramic conventionally-ligated brackets were at any time 60% more prone to failure compared to SS conventionally-ligated brackets (HR=1.6; 95% CI=1.1-2.3).
*SS, stainless steel; $_{CL}$, conventionally-ligated; $_{SL}$, self-ligated; Ni-free, Nickel-free.

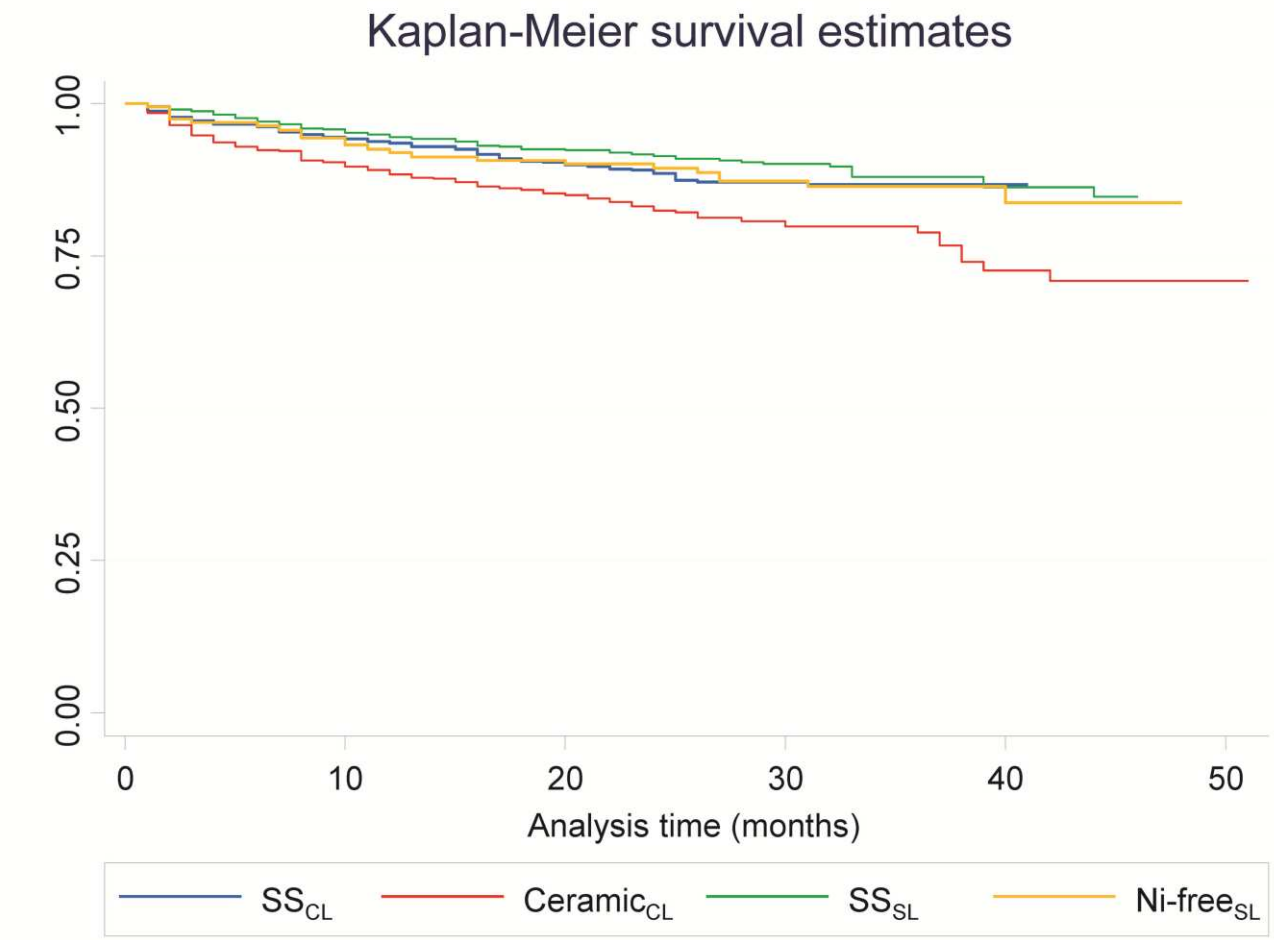

Table 1. Descriptive characteristics of the patient sample included in the present study and treated with each bracket type.

			Overall		SS_{CL}		$Ceramic_{CL}$		SS_{SL}		$Ni\text{-}free_{SL}$		
Category	**Factor**	**Category**	**n**	**%**	**n**	**%**	**n**	**%**	**n**	**%**	**n**	**%**	**P**
		Overall	78	100%	25	100%	20	100%	25	100%	8	100%	
General													
	Gender	Female	50	64%	14	56%	15	75%	16	64%	5	63%	0.63
		Male	28	36%	11	44%	5	25%	9	36%	3	38%	
	Age	Mean (SD)	78	12.6 (1.9)	25	12.2 (1.5)	20	13.3 (1.9)	25	12.4 (2.3)	8	12.8 (1.5)	0.25
Malocclusion													
	Deepbite	No	37	47%	9	36%	8	40%	14	56%	6	75%	0.18
		Yes	41	53%	16	64%	12	60%	11	44%	2	25%	
	Crossbite	No	66	85%	22	88%	18	90%	20	80%	6	75%	0.65
		Yes	12	15%	3	12%	2	10%	5	20%	2	25%	
	Anterior crowding	No	15	19%	3	12%	7	35%	2	8%	3	38%	0.05
		Yes	63	81%	22	88%	13	65%	23	92%	5	63%	
	Extraction case	No	70	90%	23	92%	18	90%	21	84%	8	100%	0.58
		Yes	8	10%	2	8%	2	10%	4	16%	0	0%	
	Auxiliary appliances used	No	72	92%	24	96%	19	95%	23	92%	6	75%	0.26
Compliance		Yes	6	8%	1	4%	1	5%	2	8%	2	25%	
	Missed appointments	Mean (SD)	78	2.5 (2.7)	25	1.8 (2.4)	20	3.0 (2.5)	25	2.8 (2.8)	8	2.8 (3.4)	0.50
	Hygiene warning given	No	37	47%	13	52%	10	50%	10	40%	4	50%	0.84
		Yes	41	53%	12	48%	10	50%	15	60%	4	50%	

SS, stainless steel; $_{CL}$, conventionally-ligated; $_{SL}$, self-ligated; SD, standard deviation.

Table 2. Summary statistics of the non-normally distributed outcome number of failed brackets per patient for different variables (P values from Kruskal-Wallis test)

Factor	Category	n	Median (IQR)	Range	P
	Overall	78	3.0 (2.0,5.0)	1.0,24.0	
Gender	Female	50	3.0 (1.0,5.0)	1.0,21.0	0.72
	Male	28	3.0 (2.0,4.5)	1.0,24.0	
Deepbite	No	37	3.0 (2.0,5.0)	1.0,13.0	0.78
	Yes	41	3.0 (2.0,5.0)	1.0,24.0	
Crossbite	No	66	3.0 (1.0,5.0)	1.0,24.0	0.38
	Yes	12	3.5 (3.0,5.5)	1.0,7.0	
Anterior crowding	No	15	4.0 (2.0,7.0)	1.0,24.0	0.27
	Yes	63	3.0 (1.0,5.0)	1.0,13.0	
Bracket type	SS_{CL}	25	3.0 (2.0,4.0)	1.0,10.0	0.14
	$Ceramic_{CL}$	20	5.0 (2.5,8.0)	1.0,24.0	
	SS_{SL}	25	3.0 (1.0,5.0)	1.0,21.0	
	$Ni\text{-}free_{SL}$	8	2.5 (2.0,4.0)	1.0,6.0	
Extraction case	No	70	3.0 (2.0,5.0)	1.0,24.0	0.75
	Yes	8	2.5 (2.0,4.0)	1.0,13.0	
Auxiliary appliances used	No	72	3.0 (2.0,5.0)	1.0,24.0	0.78
	Yes	6	3.0 (2.0,3.0)	1.0,9.0	
Missed app's (binary)	No	25	2.0 (1.0,3.0)	1.0,13.0	0.03
	Yes	53	4.0 (2.0,6.0)	1.0,24.0	
Hygiene warning received	No	37	3.0 (2.0,5.0)	1.0,24.0	0.63
	Yes	41	3.0 (2.0,5.0)	1.0,11.0	

IQR, interquartile range; SS, stainless steel; $_{CL}$, conventionally-ligated; $_{SL}$, self-ligated.

Table 3. Results of the negative binomial bi- and multi-variable regression for the identification of factors important for the number of failed brackets per patient. Results are given as unstandardized coefficients with their 95% Confidence Intervals.

		Bivariable			Multivariable	
Factor	**Category**	**Coefficient (95% CI)**	**P**		**Coefficient (95% CI)**	**P**
Gender	Female	Referent			NT	
	Male	0.05 (-2.13,2.23)	0.96		NT	
Age	Per year	-0.05 -0.68,0.58)	0.87		NT	
Deepbite	No	Referent			NT	
	Yes	1.08 (-0.99,3.16)	0.31		NT	
Crossbite	No	Referent			NT	
	Yes	-0.36 (-3.09,2.38)	0.80		NT	
Anterior crowding	No	Referent			Referent	
	Yes	-2.45 (-5.99,1.08)	0.17		-1.14 (-4.20,1.92)	0.47
Bracket type	SS_{CL}	Referent			Referent	
	$Ceramic_{CL}$	2.97 (-0.33,6.27)	0.08		1.96 (-1.22,5.15)	0.23
	SS_{SL}	0.64 (-1.62,2.90)	0.58		-0.17 (-2.15,1.82)	0.87
	$Ni\text{-}free_{SL}$	-0.28 (-3.09,2.53)	0.85		-1.53 (-4.48,1.43)	0.31
Extraction case	No	Referent			NT	
	Yes	-0.38 (-3.59,2.83)	0.82		NT	
Auxiliary appliances used	No	Referent			NT	
	Yes	-0.78 (-4.14,2.58)	0.65		NT	
Missed appointment	Per appointment	0.32 (-0.15,0.93)	0.16		0.12 (-0.24,0.59)	0.41
Hygiene warning received	No	Referent			NT	
	Yes	-0.61 (-2.72,1.49)	0.57		NT	
Tx duration	per month	0.14 (0.03,0.23)	0.009		0.10 (0.01,0.19)	0.03

CI, confidence interval; NT, not tested; SS, stainless steel; $_{CL}$, conventionally-ligated; $_{SL}$, self-ligated; Tx, treatment.

Table 4. Results of the Cox bi- and multi-variable regression for the identification of factors important for the survival of brackets. Results are given as Hazard Ratios with their 95% Confidence Intervals.

			Bivariable			Multivariable	
Factor	**Category**		**HR (95% CI)**	**P**		**HR (95% CI)**	**P**
Gender	Female		Referent			NT	
	Male		1.00 (0.73,1.38)	0.98		NT	
Age	Per year		1.00 (0.92,1.08)	0.93		NT	
Jaw	Mandible		Referent			Referent	
	Maxilla		1.30 (0.99,1.69)	0.06		1.30 (1.00,1.70)	0.05
Deepbite	No		Referent			NT	
	Yes		1.24 (0.91,1.67)	0.17		1.14 (0.85,1.52)	0.38
Crossbite	No		Referent			NT	
	Yes		0.89 (0.58,1.37)	0.60		NT	
Anterior crowding	No		Referent			NT	
	Yes		0.92 (0.63,1.34)	0.66		NT	
Mouth side	Left		Referent			NT	
	Right		1.15 (0.88,1.51)	0.30		NT	
Tooth	Central incisor		1.72 (1.05,2.83)	0.03		1.74 (1.06,2.87)	0.03
	Lateral incisor		1.87 (1.15,3.05)	0.01		1.89 (1.16,3.08)	0.01
	Canine		Referent			Referent	
	1st premolar		1.43 (0.85,2.40)	0.17		1.45 (0.86,2.43)	0.16
	2nd premolar		3.22 (2.04,5.08)	<0.001		3.19 (2.03,5.03)	<0.001
Tooth category	Posterior (canines-premolars)		Referent			NT	
	Anterior (incisors)		0.98 (0.74,1.28)	0.86		NT	
Bracket type	SS_{CL}		Referent			Referent	
	$Ceramic_{CL}$		1.64 (1.15,2.32)	0.006		1.62 (1.14,2.29)	0.007
	SS_{SL}		0.79 (0.54,1.15)	0.21		0.80 (0.55,1.18)	0.26
	$Ni\text{-}free_{SL}$		0.96 (0.58,1.60)	0.89		1.01 (0.60,1.69)	0.98
Extraction case	No		Referent			NT	
	Yes		0.85 (0.51,1.42)	0.54		NT	
Auxiliary appliances used	No		Referent			NT	
	Yes		1.00 (0.57,1.75)	1.00		NT	
Missed appointment	Per appointment		1.03 (0.98,1.09)	0.24		NT	
Hygiene warning received	No		Referent			NT	
	Yes		0.99 (0.73,1.35)	0.96		NT	

HR, hazard ratio; CI, confidence interval; NT, not tested; SS, stainless steel; $_{CL}$, conventionally-ligated; $_{SL}$, self-ligated; Tx, treatment

Table 5. Results of the linear bi- and multi-variable regression for the identification of factors important for treatment duration. Results are given as unstandardized coefficients with their 95% Confidence Intervals.

		Bivariable			Multivariable	
Factor	**Category**	**Coefficient (95% CI)**	**P**		**Coefficient (95% CI)**	**P**
Gender	Female	Referent			NT	
	Male	1.69 (-2.23,5.62)	0.39		NT	
Age	Per year	-0.19 (-1.18,0.80)	0.70		NT	
Deepbite	No	Referent			NT	
	Yes	-1.17 (-4.95,2.61)	0.54		NT	
Crossbite	No	Referent			Referent	
	Yes	4.08 (-1.08,9.24)	0.12		1.35 (-3.33,6.03)	0.57
Anterior crowding	No	Referent			NT	
	Yes	-1.12 (-5.92,3.67)	0.64		NT	
Bracket type	SS_{CL}	Referent			Referent	
	$Ceramic_{CL}$	1.38 (-3.50,6.26)	0.58		-1.53 (-6.03,2.98)	0.50
	SS_{SL}	4.60 (0.00,9.20)	0.05		2.75 (-1.38,6.87)	0.19
	$Ni\text{-}free_{SL}$	6.63 (0.03,13.23)	0.05		6.47 (0.57,12.36)	0.03
Extraction case	No	Referent			Referent	
	Yes	7.10 (1.08,13.12)	0.02		7.31 (1.77,12.86)	0.01
Auxiliary appliances used	No	Referent			NT	
	Yes	1.49 (-5.61,8.58)	0.68		NT	
Missed appointments	Per appointment	1.02 (0.34,1.69)	0.004		0.82 (0.19,1.46)	0.01
Hygiene warning received	No	Referent			NT	
	Yes	-0.96 (-4.75,2.82)	0.61		Referent	
Number of bracket failures	per failure	0.58 (0.14,1.03)	0.01		0.63 (0.21,1.05)	0.004

CI, confidence interval; NT, not tested; SS, stainless steel; $_{CL}$, conventionally-ligated; $_{SL}$, self-ligated; Tx, treatment

Bracket loss during orthodontic treatment and its influence on treatment duration: A retrospective cohort study

Appendix 1. Summary statistics of bracket failure by characteristic (P values from chi-square)

Factor	Category		Failure (first time)		
			No	Yes	P
	Overall		1328 (86.0%)	217 (14.1%)	
Gender	Female		856 (86.2%)	137 (13.8%)	0.706
	Male		472 (85.5%)	80 (14.5%)	
Jaw	Mandible		677 (87.6%)	96 (12.4%)	0.066
	Maxilla		651 (84.3%)	121 (15.7%)	
Deepbite	No		640 (87.2%)	94 (12.8%)	0.182
	Yes		688 (84.8%)	123 (15.2%)	
Crossbite	No		1125 (85.9%)	184 (14.1%)	0.976
	Yes		203 (86.0%)	33 (14.0%)	
Anterior crowding	No		254 (85.0%)	45 (15.1%)	0.578
	Yes		1074 (86.2%)	172 (13.8%)	
Mouth side	Left		670 (86.9%)	101 (13.1%)	0.286
	Right		658 (85.0%)	116 (15.0%)	
Tooth	Central incisor		271 (86.9%)	41 (13.1%)	<0.001
	Lateral incisor		267 (85.6%)	45 (14.4%)	
	Canine		287 (92.0%)	25 (8.0%)	
	1st premolar		267 (88.7%)	34 (11.3%)	
	2nd premolar		236 (76.6%)	72 (23.4%)	
Tooth category	Posterior (canines-premolars)		790 (85.8%)	131 (14.2%)	0.806
	Anterior (incisors)		538 (86.2%)	86 (13.8%)	
Bracket type	SS_{CL}		436 (87.7%)	61 (12.3%)	0.001
	$Ceramic_{CL}$		316 (80.0%)	79 (20.0%)	
	SS_{SL}		438 (88.8%)	55 (11.2%)	
	$Ni\text{-}free_{SL}$		138 (86.3%)	22 (13.8%)	
Extraction case	No		1204 (86.0%)	196 (14.0%)	0.873
	Yes		124 (85.5%)	21 (14.5%)	
Auxiliary appliances used	No		1227 (86.0%)	199 (14.0%)	0.724
	Yes		101 (84.9%)	18 (15.1%)	
Missed appointments (binary)	No		442 (89.1%)	54 (10.9%)	0.014
	Yes		886 (84.5%)	163 (15.5%)	
Hygiene warning received	No		628 (85.7%)	105 (14.3%)	0.764
	Yes		700 (86.2%)	112 (13.8%)	

SS, stainless steel; $_{CL}$, conventionally-ligated; $_{SL}$, self-ligated.

Appendix 2. Summary statistics of treatment duration by characteristic (P values from 1-way ANOVA and t-tests)

Factor	Category	n	Mean (SD)	P
	Overall	78	30.6 (8.3)	
Gender	Female	50	30.0 (8.6)	0.393
	Male	28	31.7 (7.8)	
Deepbite	No	37	31.2 (8.6)	0.540
	Yes	41	30.1 (8.2)	
Crossbite	No	66	30.0 (7.8)	0.119
	Yes	12	34.1 (10.4)	
Crowding	No	15	31.5 (9.3)	0.643
	Yes	63	30.4 (8.2)	
Bracket type	SS_{CL}	25	28.1 (6.8)	0.102
	$Ceramic_{CL}$	20	29.5 (9.7)	
	SS_{SL}	25	32.7 (7.9)	
	$Ni\text{-}free_{SL}$	8	34.8 (8.8)	
Extraction case	No	70	29.9 (8.2)	0.022
	Yes	8	37.0 (6.8)	
Auxiliary appliances used	No	72	30.5 (8.2)	0.678
	Yes	6	32.0 (10.9)	
Missed appointments (binary)	No	25	28.5 (8.9)	0.126
	Yes	53	31.6 (7.9)	
Hygiene warning received	No	37	31.1 (8.9)	0.613
	Yes	41	30.2 (7.9)	

SD, standard deviation; SS, stainless steel; $_{CL}$, conventionally-ligated; $_{SL}$, self-ligated.